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REPAIR OF BRIDGES ON AUTOMOBILE ROADS

Chapter IX. TEMPORARY REPAIR OF REINFORCED-CONCRETE AND STONE BRIDGES

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/Note: Figures referred to herein are appended./

A. General Data

The destruction of reinforced-concrete and stone bridges caused by military operations is extremely varied by its very nature. Because of their great massiveness and considerable three-dimensional rigidity, reinforced-concrete and also stone bridges in many cases do not collapse even when considerable damage is caused by the force of explosions.

Small blasts usually cause only insignificant local damage in structures. Powerful charges may successfully demolish reinforced-concrete bridges, and when they fall, large cracks are produced, but, in the majority of cases, they do not crumble into small separate pieces. Stone bridges, demolished by powerful charges, usually crumble into separate pieces in falling.

In stone and reinforced-concrete bridges small, local damages caused by the detonation of land mines, mines, aerial bombs or artillery shells, in cases where they do not lead to the collapse of the structures, usually admit of temporary restoration without any special difficulty.

If, however, as a consequence of structural damage, reinforced-concrete or stone bridges collapse, restoration work is generally very difficult.

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The difficulty lies in the fact that fallen parts of the reinforced-concrete structure that block the riverbed admit of dismantling and removal only with great difficulty, and, at the same time, greatly impede the erection of any temporary structure along the axis of the destroyed bridge. Furthermore, utilization of the fallen parts of destroyed reinforced-concrete bridges by raising them, as a rule, is found to be impossible owing to the great destruction of the concrete in fallen structures and to damage due to their monolithic nature.

In stone bridges also, the parts which have fallen in put great obstacles in the way of restoration work, although their dismantling and removal from the riverbed is simpler than in the case of reinforced-concrete bridges.

Utilization of the fallen-in portions of stone bridges in restoration work is possible only by dismantling the layer of fallen stone into separate pieces which can be used again in laying the restored structure of the bridge.

B. Temporary Restoration of Stone Bridges

In demolished stone bridges, one or more of the arches, and, in some cases, the supports may fall in as well.

In the course of temporary restoration, the fallen-in parts of the stone bridges are, as a rule, replaced by beam-span structures with wooden or metal bearers. In addition, the beam-span structures rest on those parts of the masonry which are intact.

As the work of clearing the riverbed of rubble from the fallen masonry is fairly difficult, installing intermediate supports is avoided in the majority of cases.

In single-span stone bridges where the arch has been completely destroyed, the gap is bridged by a beam-span structure (Figure 95), resting immediately on the intact part of the masonry (right end in the figure) or in a superstructure of framework (left end), cages (kletki), or masonry taken from the broken pieces of the structures.

In cases where only a small part of the arch is demolished, it is necessary to take measures to keep the intact portion from falling. For this purpose a girder installation between the ends of the preserved parts of the arch (Figure 96, a) may be used, or supports may be erected under their ends (Figure 96, b). Both girders and additional supports must be firmly wedged to ensure their efficiency.

The supports of the beam-span structure which bridge the gap should be placed over the buttresses (Figure 96, a), with transmission of the bearing pressure partly on the arch permitted only as a last resort (Figure 96, b). Furthermore, the underside of beam-span structures must be placed somewhat above the preserved parts of the arch so that when the girders give under a load they will not rest on the arch.

In stone bridges with several spans, the method of temporary repair depends on the nature of the destruction, the size of the spans, and the height of the bridge. When the arches in all the spans are destroyed and the supports are partly preserved, the most advisable temporary repair is an installation of beam-span structures laid upon the intact supports or upon a superstructure on what remains of them (Figure 97).

 [redacted]

In fairly low bridges where it is possible to clear away or level the fallen rubble, the spans may be completely filled in by wooden posts or frame structures (see the first span in Figure 98).

When a stone bridge with several spans has been blown up in parts of its length, the remaining spans are usually intact, in spite of the fact that the last support of the intact part is subject to a great unilateral thrust. In this case, in order to make it possible to use the preserved part of the bridge and to obviate a dangerous unilateral effect upon the last support, steps are taken to receive the thrust of the last span of the part still standing. For this purpose, use may be made of a metal tie rod (Figure 98) or of a strong brace in the form of a rigid structure (ramm), with its upper end against the top of the support and its lower end on the adjacent support at a bevel of the foundation (Figure 99).

In both cases wedging must be provided in the construction work to receive the thrust by means of the tension of the tie beam, or by wedging the brace.

In case only one span of the bridge is demolished, use may be made of a tie-rod layout similar to that in Figure 96, a, or the gap may be filled by a scaffold, the upper part of which is used as a strut (Figure 100). The scaffold is put in place by jacks and wedges.

The intensity of the thrust transmitted to the tie rod, strut, or brace must be determined from the effect of the weight of the arch itself, together with the part above the arch and the temporary load. Moreover, the added thrust arising from changes of temperature must also be studied.

In restoring stone bridges with large spans, the destroyed sections must be spanned with wooden lattice girders or metal sectional span structures.

C. Temporary Repair of Reinforced-Concrete Bridges

1. General Data

Temporary repair methods for damaged or demolished reinforced-concrete bridges depend, in the first instance, on the nature and degree of the destruction, and also on the plan and structure of the bridge.

In case of minor damage to a bridge, which does not entail collapse of the structure nor, on the whole, essentially detract from the over-all carrying capacity, temporary repair consists of filling in or covering over the breaks or damaged parts and, in case of necessity, adding supports under the bearing parts weakened by a detonation. In addition, repairs are made, as a rule, by using wood as a structural material.

When the destruction is more serious and entails the collapse of part of the structure, temporary repair must be effected by building up the gap formed in the bridge. This is done by means of a wooden scaffold or by bridging over the destroyed part with wooden, or, in individual cases with metal-span structures.

In every case where it is necessary to bridge over demolished parts of a reinforced-concrete bridge with a wooden structure, great difficulties usually arise in erecting intermediate supports because fragments from the fallen structure clog the riverbed and it is difficult to clear them away.

In all cases, where the fallen debris is sufficiently firm, the supports of the temporary structure can be set up on it. Otherwise, the span structures of the repaired part must rest on the intact supports of the demolished bridge or what remains of them, making, if need be, a superstructure upon them.

When a considerable part of the length of a reinforced-concrete bridge is demolished, or when the bridge is completely demolished, temporary repair must be effected by building a new bridge on a by-pass or on a new line.

2. Repair of Local Damage to the Roadway

Local damage to reinforced-concrete bridges in the form of breaks, holes, or partial destruction of individual elements is very often encountered as a result of air or artillery bombardment, mine-laying on parts of the bridge's roadway, or attempts to blow up the bridge by charges of insufficient power. Temporary repair of local damaged parts is effected by the simplest possible methods.

For temporary repairs, breaks through the roadway plate (plita) not effecting the beams are usually closed by wooden planks (shchit). For this purpose, the edges of the break are cleaned and the asphalt surface along its perimeter and the protective layer, with the insulation, are cut back to a width of 10-15 cm. According to the size of the break, boards or beams are laid on the edges thus formed. A floor board (flush with the roadway) is attached to the upper surfaces of these boards or beams (Figure 101). To keep this wooden planking from moving, metal dowels are used which pass through the planking into sockets pierced in the concrete and embedded in them by means of wooden plugs or by pouring in a cement solution.

Large breaks cannot be bridged over by simple wooden planks. A more complicated procedure is necessary to close them -- for example, by placing under the damaged place metal beams which rest on the ribbing of the plate in holes specially pierced in the latter, or in niches (Figure 102).

If the damage is only a hole in the roadway (without a break clear through), the method of repair depends upon the depth of the damage sustained.

If the hole only grazes the protective layer and does not touch or touches only slightly the reinforced concrete plate, filling in may be done by closing such holes with concrete, asphalt, or even gravel, rubble, or other material, on a level with the roadway's surface.

In cases where the plate has been badly damaged or where, by the action of a blast, the concrete of the plate has sustained a clear break through its whole thickness (characterized by pronounced splitting or even by reduction of the protective layer to powder), it is necessary to bridge over the damaged part in a manner similar to the bridging of through breaks.

If the beams of the roadway section of the bridge are damaged by an explosion, but the main beams remain intact, temporary repairs may be effected by placing under the damaged section additional wooden or metal beams which rest on the main beams of the bridge in sockets made for this purpose or in holes in the concrete of their edges. Wooden blocks are laid on the added auxiliary beams and the damaged reinforced-concrete beam is raised by means of chocks (Figure 103). The chocks must be secured by cramps or spikes to prevent displacement while the bridge is in use.

When the bridge is not very high, it may be found advisable to reinforce the damaged roadway beams by placing under them additional wooden supports which rest directly on the ground or on piles. Figure 104 is a diagram of the temporary repair of a damaged cross beam of a reinforced-concrete bridge, which repair was accomplished by placing an additional wooden support under the damaged part.

The damaged beam must be securely wedged; moreover, inasmuch as the added support will tend to settle, the wedge must be tamped periodically while the bridge is in operation. Wooden planking bridges over the break in the plate.

Damaged parts of the roadway and the structure over the arches of bridges with reinforced-concrete arches are temporarily repaired similar to the above-described procedure. When explosion causes damage to the roadway, beams, or pillars of the arch, temporary repairs are made by erecting (under the damaged places) wooden or metal beams and posts which rest on the arches or vault of the bridge (Figure 105).

3. Repair of Damage to Main Bearer Parts

In local damage to the main beams, temporary repair is carried out by placing additional supports under the damaged beam. When the outside beams are damaged, it is only in wide bridges that operation can be carried on by admitting traffic along the undamaged part of the broad roadway.

In case of minor damage to a deck bridge, a pile or pile-and-frame support (Figure 106) is placed under the damaged part and connected with the deck portion by secure wedging. Hollow places are filled with concrete or other material.

If it is not possible to add a support directly under the damaged place, recourse is had to reinforcing the damaged part by arranging to prop it up with additional beams resting on special additional supports. Figure 107 shows the temporary repair of a reinforced-concrete viaduct with damaged main beams on a span over railway lines. In view of the impossibility of adding supports directly under the damaged place, use is made in this case of metal double-T beams, installed along the sides of the damaged reinforced-concrete beams and resting with their ends on wooden log supports erected immediately adjacent to the reinforced-concrete pillars of the viaduct. On the lower flanges of the double-T beams lie short wooden cross pieces which support the damaged beams by means of wedges.

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If the damage is so great that the main beam is completely out of commission in some section, additional supports are erected under the intact part of the main beams (along the edges of the damage). In some cases, a wooden scaffold is erected in the damaged part of the structure. Figure 108 shows temporary repair of a frame trestle bridge in which an explosion has destroyed the support, together with sections of the adjacent main beams.

Here, to replace the fallen structure a wooden pile frame trestle was erected which supported the wooden planking filling the break in the roadway; the ends of the supporting parts of the main beams are propped up by pile-frame supports with a solid chock.

If the preserved parts of the main beams sag as a result of the damage, it is necessary (when temporary supports are placed under them), to use jacks to raise the sunken ends up to their normal position and to fix them in this position on temporary supports by means of dependable wedges.

If the destruction of one of the spans materially upsets the static plan of the installation and causes overloading on the neighboring spans, use may also be made of additional supports on the spans adjacent to the damaged part. Thus, for example, when the suspension beam of a cantilever bridge (Figure 109, a) or the middle span of a continuous bridge (Figure 109, b) is destroyed, both methods -- filling in the resultant break and adding supports in the middle of the adjacent spans -- may be employed.

In local damage to the arches or vaults of arched bridges under temporary repair, supports (Figure 110) are added under the damaged part and joined to the work by means of jacks or wedges.

4. Repair of Destroyed Reinforced-Concrete Bridges

When a reinforced-concrete bridge has been completely destroyed along its whole length or in a section of its length, temporary repairs are effected by building up the destroyed sections with wooden structures (Figure 111 /photograph; not reproduced/) or by building a new bridge to by-pass it.

In restoring completely demolished, small reinforced-concrete bridges, clearing the aperture of debris does not entail special difficulties, and, therefore, it seems advisable to erect the simplest wooden bridge in place of the demolished installation.

Figure 112 shows the repair of a demolished, small, single-span reinforced-concrete bridge.

The span structure, the upper parts of the piers, and sections of the embankment adjacent to them were completely destroyed in the collapse. The pier foundations were preserved, but the upper part of them was damaged. For repair, use was made of a two-span wooden bridge of a simple beam plan, on pier supports. The use of the preserved parts of the foundations on which to erect supports for a wooden bridge was not admissible because of uncertainty as to the adequate stability of their base which had been greatly damaged by the blast.

Therefore, there was selected for the bridge a plan whereby the piles of the supports did not rest on the remains of the pier foundations. In order to erect the wooden bridge, the bed of the stream was cleared of debris from the fallen structure. If the bridge supports had been partly or wholly preserved and their base had not suffered any material damage, it would have been feasible, when the restoration was being effected, to use them for a temporary wooden bridge. Figure 113 shows the repair of a demolished single-span reinforced-concrete bridge (1. = 12.5 meters)

Of this bridge, one pier and the foundation of another were intact. The reinforced-concrete-span structure and the part of the left pier above ground were completely destroyed. Restoration was effected by construction of a new wooden bridge in accordance with a very simple beam plan.

The bed of the stream was bridged over by two spans with double-beam bearers. The destroyed abutment was bridged over by two spans with single-beam bearers. The middle support and the supports behind the destroyed abutment were formed by piers. But the support located within the limits of the preserved foundation of the destroyed abutment was of frame-log construction.

To set up this support, the preserved part of the abutment was levelled to horizontal surfaces, on which were laid ground plates that were fastened in the concrete by metal cramps.

As pile supports may settle when the bridge is in use, the frame supports were erected on a massive foundation, and the bridge structure spanning the abutment was adapted to possible forms of settling. For this purpose, the bearers on support No 2 (Figure 113) had joints ["No 2" not numbered in figure]. In addition, the connection of this support with the ground plate was made by merely horizontal gripping devices only, without erecting struts or diagonal gripping devices.

In high bridges the use of short-span wooden structures in temporary restorations is not advantageous.

If the demolished bridge had comparatively short spans, the temporary bridge would be erected with the same spans, utilizing, if possible, the preserved parts of the supports. Figure 114 shows the repair of a three-span bridge preserving the same spans. The frame supports of the repaired bridge were constructed on the preserved parts of the foundation of the supports of the demolished bridge; the spans were bridged by compound wooden beams on oak laminated dowels.

If the demolished bridge were of reinforced-concrete-span construction with large spans, the spans would be bridged over for restoration purposes with wooden lattice span structures, most frequently with wooden lattices of boards nailed together. Moreover, so as not to complicate the structural work of erecting the bridge by cleaning the riverbed, an effort would be made to use for the repaired bridge the same spans as those of the demolished bridge. Only if it were impossible completely to bridge over these spans would they be dismantled, and additional supports built (it would first be necessary to clear the riverbed of debris in order to erect these supports).

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Temporary repair of reinforced-concrete-arch bridges that have been demolished is effected in a manner similar to the repair of stone bridges. Arched bridges that have been completely demolished are generally replaced in temporary repairs by some beam spans with wood or metal bearers (Figure 115).

In multispan reinforced-concrete-arch bridges with individual span structures demolished, it often proves possible to utilize the preserved spans for the passage of traffic without having to take any measures to receive the unbalanced thrust. This is feasible because of the possibility of increasing the permissible strain (decreasing safety and stability factors) in the temporary repair, and also because of the increase in the stability of concrete in the course of time and the better quality now available than that specified in the plan.

Figure 116 is a diagram of an interesting case of the repair of a reinforced-concrete-arch bridge over the Luga River at Kingisepp; in this bridge only one middle span and its retaining supports were preserved. When temporary repairs were being made, the possibility was seen of utilizing this span by transmitting the considerable unilateral thrust to the supports. The end sections of the bridge were repaired by constructing them with wooden span structures.

A general view of the repaired bridge is shown in Figure 117 [photograph; not reproduced.].

[Appended figures follow.]

Figure 95. Restoration of a Single-Span Stone Bridge

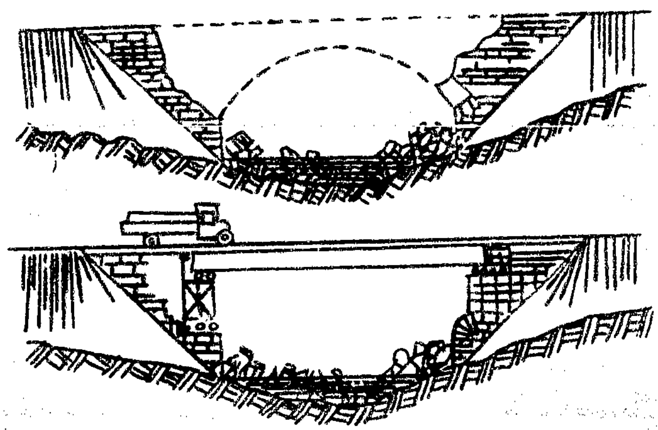
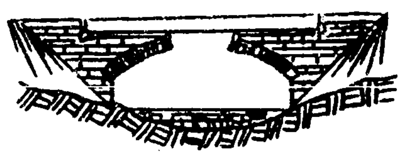


Figure 96. Bridging Over Partly-Demolished Stone Arches

(a)



(b)

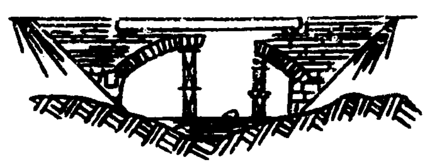


Figure 97. Temporary Repair of a Completely-Demolished Stone Bridge

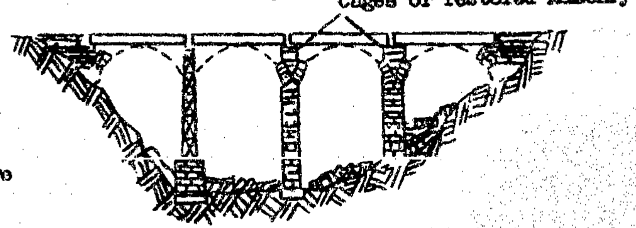


Figure 98. Temporary Repair of a Stone Bridge Where the Thrust of the Last Span Is Received by Aid of Tie Rods

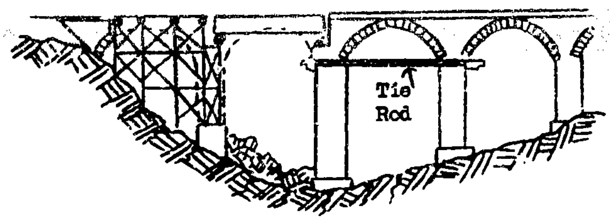


Figure 99. Receiving the Thrust of the Last Span With the Aid of Braces

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Figure 100. Filling in a Demolished Span by Means of a Scaffold Used as a Strut

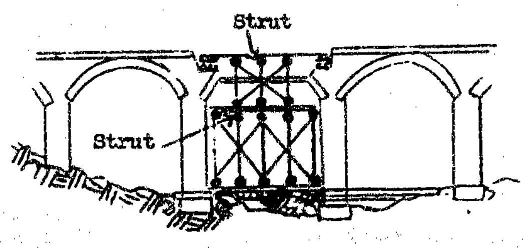

Figure 101. Closing a Break in the Roadway Plate

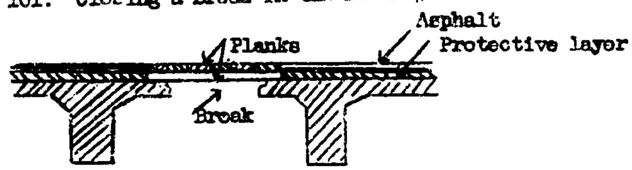

Figure 102. Closing a Break in the Roadway Plate by Means of Metal Beams

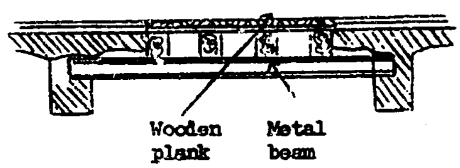

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Figure 103. Temporary Repair of a Damaged Beam Under the Roadway

(1) Auxiliary beam

(2) Chock

(3) Main beam

(4) Damaged cross beam

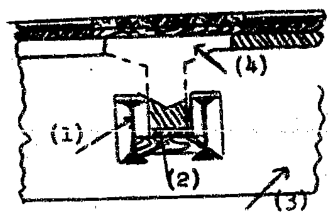


Figure 104. Temporary Repair of a Damaged Cross Beam by Placing a Wooden Support Under It

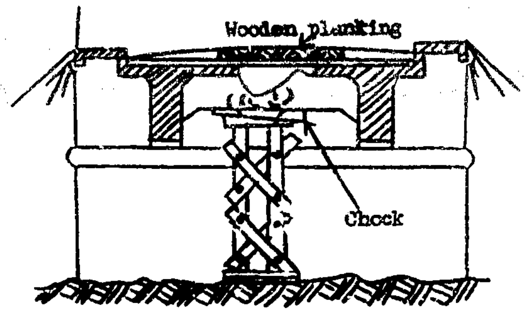


Figure 105. Temporary Repair of the Damaged Structure Over the Arch

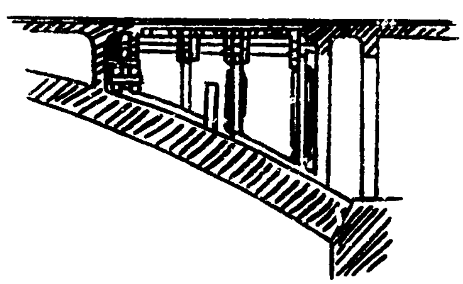


Figure 106. Adding Supports Under the Damaged Span of a Deck Bridge

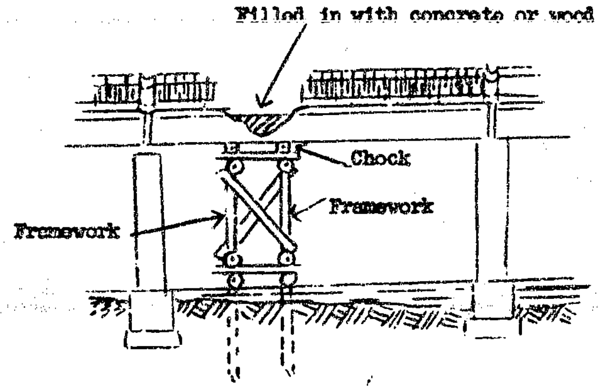
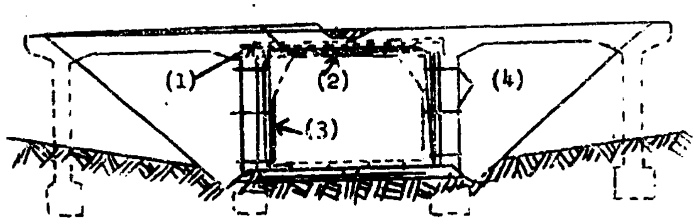


Figure 107. Temporary Repair of a Damaged Reinforced-Concrete Viaduct



(1) Metal double-T beam

(2) Wooden cross piece

(3) Wooden structure

(4) Hoops

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Figure 108. Temporary Repair of a Demolished Part of a Reinforced-Concrete Trestle

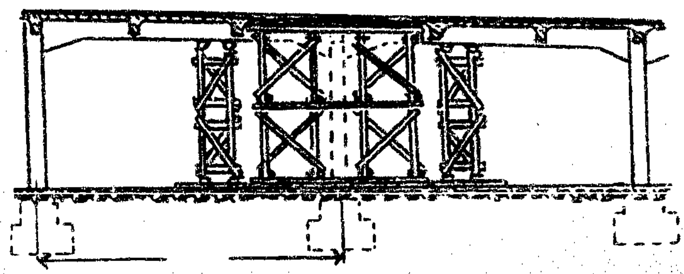

Figure 109. Diagrams of Temporary Repair by Adding Supports in the Spans Adjacent to Those Damaged

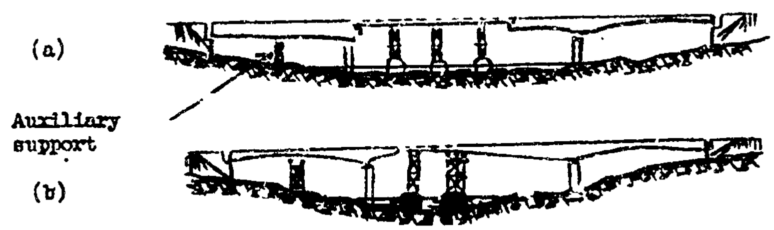

Figure 110. Temporary Repair of a Damaged Arch Bridge

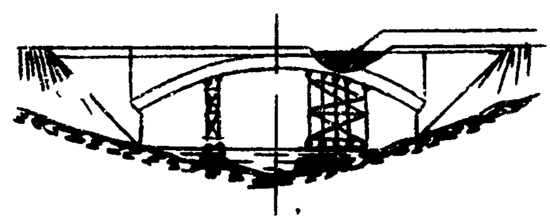

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Figure 112. Temporary Repair of a Completely Demolished, Small, Single-Span Reinforced-Concrete Bridge

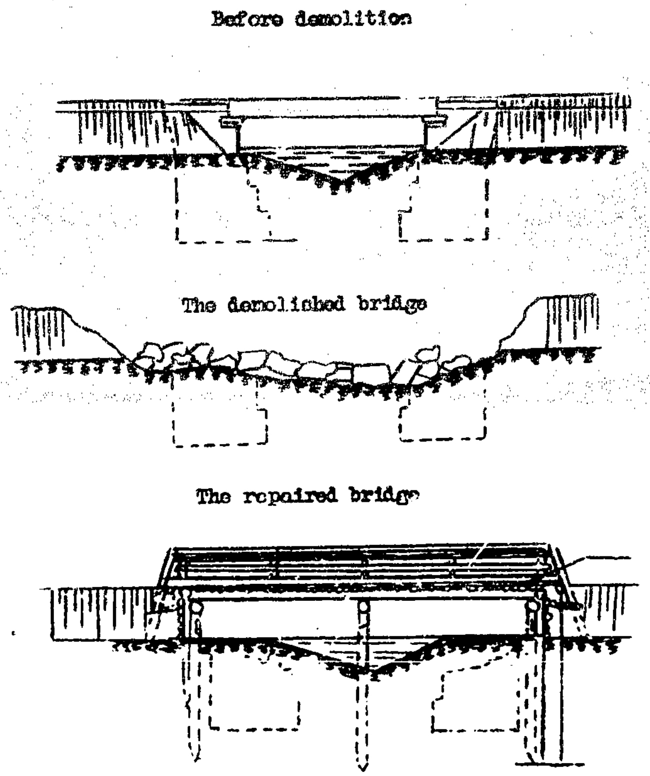

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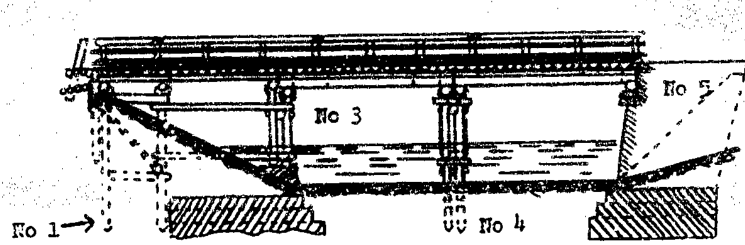
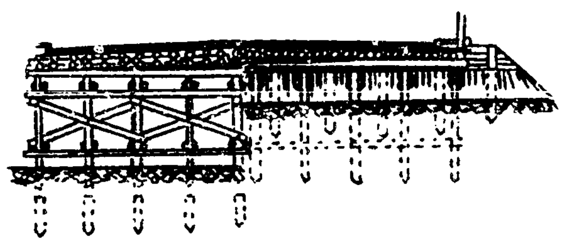
Figure 113. Temporary Repair of a Demolished Reinforced-Concrete Bridge With a Small Span





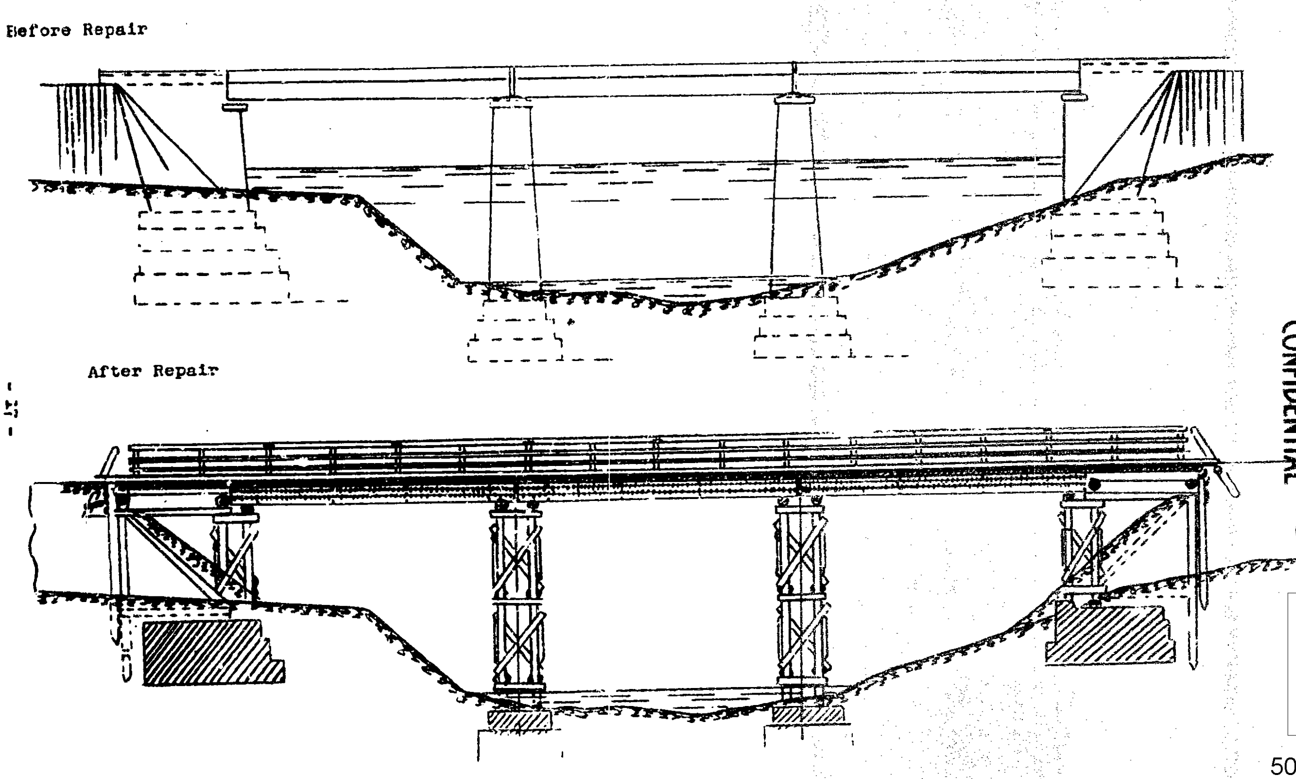


Figure 114. Temporary Repair of a Three-Span-Beam, Reinforced-Concrete Bridge

Figure 115. Temporary Repair of a Reinforced-Concrete-Arch Bridge

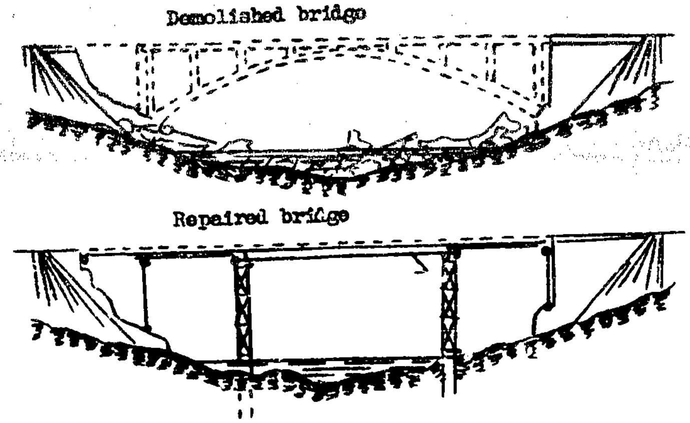


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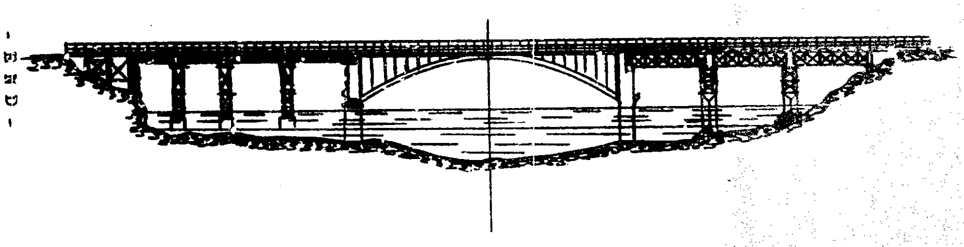
Figure 116. Temporary Repair of a Three-Span Reinforced-Concrete-Arch Bridge



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